Confirmation of laryngeal mask airway placement by ultrasound examination: a pilot study

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Abstract

Study Objective: We sought to validate ultrasound against other established methods of confirming laryngeal mask airway (LMA) placement.
Design: An observational study.
Setting: A university teaching hospital, operating department.
Patients: Fifty-eight patients undergoing general anesthesia using an LMA Supreme supraglottic airway device.
Interventions: The position of the LMA was assessed by ultrasound in 3 planes: the pharynx, the larynx, and along the cranial-caudal axis in the midline. The leakage test at 20 cm H2O and fiberoptic examination were also undertaken independently, with the latter being used to detect suboptimal placement (in which case, the LMA was reinserted).
Measurements: We scored the position of the LMA based on the location of the cuff and whether it had inflated correctly in each of the 3 planes. This score was converted to correspond with the leakage test grading system. We tested the strength of the correlation between the scores and the sensitivity and specificity for predicting reinsertion.
Main Results: Seven patients (12.1%) required LMA reinsertion, and ventilation was inadequate in a further 6 (10.3%). Three patients (5.2%) developed laryngospasm and inspiratory stridor after insertion resulting in inadequate ventilation, but none needed reinsertion as optimal placement was confirmed by fibroscope. Spearman coefficient of rank correlation between the leakage test and ultrasound examination was 0.713 (P<.0001). The κ test and Bland-Altman analysis showed good agreement between the 2 scoring systems (weighted κ = 0.605, standard error = 0.086). An ultrasound examination score equating to grade 3 in the leakage test predicted the need for reinsertion with a sensitivity and specificity of 85.7% and 94.1%, respectively.

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1. Introduction

The laryngeal mask airway (LMA) is widely used as an effective and safe airway adjunct in the routine practice of anesthesia. It is easier to insert an LMA than an endotracheal tube, but there is a greater likelihood of misplacement. Anesthesiologists may not always be able to confirm the exact position of an LMA promptly, potentially resulting in inadequate ventilation, the need for reinsertion, and, if ventilation is not possible for some time, hypoxemia. To avoid these complications, it is essential to be able to determine the reason for inadequate ventilation quickly. Although misplacement is the most common cause, there are many others, such as laryngospasm, that cannot be solved by reinserting the LMA. Indeed, in the event that misplacement is not the cause of inadequate ventilation, an unnecessary attempt at reinsertion would further interrupt ventilation, which in turn further exacerbates existing hypoxemia.

Current methods to assess LMA placement include the following: auscultation, the leakage test, insertion of a suction tube into the drainage conduit if an LMA ProSeal (Teleflex Medical, Shanghai, China) is used, the bubble test, and fiberoptic examination. The leakage test is used most often and, under most circumstances, is good enough to judge LMA placement, even in children [1,2]. However, the technique is not completely reliable, meaning that incorrect placement may not immediately be recognized until an adverse event has occurred, especially in some long cases. Fiberoptic examination and grading of placement into one of 5 grades is thought to be the most precise means of judging LMA position [1,3]. Nonetheless, the categorization of LMA placement was established to describe the position of a traditional single-tube LMA, which has a bar in the middle of the conduit to prevent the epiglottis obstructing the tube. Newer LMA devices that have substantially different designs are now available, for example, the double-lumen airways that have entered routine clinical practice in many countries. Furthermore, although the position of an LMA may be easily evaluated with a fibroscope, there is no consensus as to how the categorization should be used to inform the need for reinsertion. In 2009, Timmermann et al [4] suggested using only 2 categories to describe LMA positioning: optimal and suboptimal, with the latter indicating the need for reinsertion, which is arguably a more practical approach. However, fiberoptic examination is an invasive method, requires ventilation to be interrupted, and may result in contamination of the airway by secretions. Anesthesiologists need an effective and reliable method to confirm LMA placement definitively without interrupting ventilation.

Conclusions: Ultrasound examination is a fast, noninvasive and reliable means of detecting LMA misplacement that agrees closely with the leakage test. Ultrasound is as effective as a fiberoptic examination to confirm LMA placement and indicate the need for reinsertion, but does not require ventilation to be interrupted. © 2016 Elsevier Inc. All rights reserved.

2. Materials and methods

Conduct of the study was approved by the Human Research Committee of the Peking Union Medical College Hospital. After giving informed consent, we enrolled 58 patients undergoing elective surgery in which the LMA Supreme (Teleflex Medical) was used as the airway adjunct. Exclusion criteria included evidence suggesting difficult intubation, history of airway stenosis, airway mass, hyperthyroidism, goiter, carotid stenosis, bowel obstruction, gastroesophageal reflux, aspiration, and history of neck surgery. All patients recruited were judged to be American Society of Anesthesiologists physical status I or II, and underwent general anesthesia in the supine position.

The LMA Supreme was deflated before insertion, and the cuff was coated with lidocaine gel. Anesthesia was induced intravenously with fentanyl 2 μg/kg and a target-controlled infusion of propofol set to 6 μg/mL plasma concentration. When the effect site concentration reached 4 μg/mL and the modified observer’s assessment alert/sedation score was lower than 1, one clinician inserted an LMA Supreme with a standard one-handed rotation maneuver, with the patient’s head in the neutral position. The LMA was inflated with 20 mL air for size 3 and 30 mL for size 4. The target concentration of propofol was decreased to 3.0 to 3.5 μg/mL for maintenance. A neuromuscular blocker was not administered. Patients were mechanically ventilated with volume-controlled ventilation, with 8-mL/kg tidal volume and a frequency of 10 to 12 breaths/min. An attempt was made to insert a suction tube through the drainage conduit after LMA placement.

2.1. Evaluation of LMA placement

Three different anesthesiologists (none of them were anesthesia provider) assessed the placement of the LMA in 3 different ways: one independently evaluated whether air leakage...
could be detected at continuous airway pressure of 20 cm H2O, a second evaluated LMA placement using ultrasound (Philips CX50, linear transducer 12-3, Bothell, WA) on the other side of a drape, and a third then used a fiberoptic endoscope (KARL STORZ, Tuttingen, Germany) to evaluate LMA placement and quickly take a photograph for further analysis.

The ultrasound examination was performed simultaneously with the leakage test and took about 1 minute. Three standard image planes were obtained. The first was in the transverse plane between the hyoid and thyroid bones (THT). The typical view is one of a cuff shadow sitting on each side of the midline symmetrically, with a smooth, plump cuff edge (Fig. 1). If it was difficult to identify the cuff, its position was identified by deflating and reinflating. The second image plane was the transverse plane at the lateral suprasternal notch (TLS). The typical view in this plane was the upper end of the esophagus posterior to the trachea. Correct placement requires the tip of the cuff to sit directly on the upper end of the esophagus without rotation or folding; thus, if the transducer was moved cranially along the midline, the image of the upper end of the esophagus (Fig. 2A) would transform into the cuff tip, manifest as an almost round shadow with a clear border displacing the esophagus (Fig. 2B). The last image plane was acquired from the second one: the transducer was rotated 90° from the last plane while keeping the esophagus in the center of the image, allowing the parasagittal plane of the pharynx and larynx (PPL) to be observed. The typical image in this plane includes a sharp, clear view of the edge of the cuff; the shadow of the cuff looking like a snake’s head; and the sagittal plane of the esophagus at the tip of the cuff. When the suction tube was inserted, it could be detected as a “dual-track sign” between the cuff tip and the proximal esophagus (Fig. 3).

The ultrasound scoring system was based on the location of the cuff and whether it had inflated correctly (Table 1; Fig. 4). Any condition that did not meet these criteria in each plane was allocated 1 point. One point was awarded in the THT plane if the 2 cuff shadows were not symmetrical or the cuff edge was flat and rigid rather than plump. In the TLS plane, 1 point was awarded if the cuff shadow did not displace the esophagus when the transducer was moved proximally, or if the edge of the cuff tip was distorted and irregular. In the PPL plane, 1 point was awarded if it was not possible to see the cuff tip and esophagus in the same plane, or if the cuff edge was distorted and obscure. Thus, 0 point means the placement is perfect, whereas 6 points indicate an unacceptable placement. However, for comparison of the ultrasound examination with the leakage test grade system [2], we defined a grading system based on the ultrasound score. So that grade 1 was equivalent to an ultrasound examination score of 0, grade 2 to 1 to 2 points, grade 3 to 3 to 4 points, and grade 4 to 5 to 6 points (Table 2). The clinical air leakage test grading system was based on the work of Kundra et al [2]. Briefly, grade 1 equated to no leak, grade 2 to a moderate leak but with satisfactory ventilation, grade 3 to a severe leak with inadequate ventilation, and grade 4 to total obstruction with no ventilation possible.

Placement of the LMA assessed by fiberoptic examination was categorized into 1 of 2 grades as already described [4]. The fiberoptic endoscope was typically positioned just proximal to the end of the ventilatory conduit, and then an attempt was made to advance it under the epiglottis in to see the vocal cords. Optimal placement was defined as the tip of the LMA lying behind the arytenoids with a visible epiglottis, without folding or intrusion into the airway, and with the vocal cords visible when the fiberscope was advanced under the epiglottis. All other situations were defined as suboptimal placement. We only used the fiberoptic evaluation to determine the need for reinsertion.

### 2.2. Statistical analysis

The correlations between the ultrasound examination and clinical leakage test were analyzed by the Spearman rank correlation test in which a P value <.05 was considered statistically significant. The κ coefficient test and Bland–Altman analysis were used to test agreement between the 2 methods. We used receiver operator characteristic curves to determine a threshold for LMA reinsertion based on fiberoptic evaluation. The incidence of optimal placement of the LMA Supreme at the first attempt had previously been reported as 100% [4], but the incidence of placements scoring 3 or 4 on our ultrasound grade was not known. Thus, a sample size was calculated to ensure that the study was adequately powered and to minimize bias. MedCalc (Version 11.4.2, Ostend, Belgium) was used for all calculations and analyses.

### 3. Results

Seven of 58 patients (12.1%) required reinsertion, including one with moderate leakage but suboptimal placement.
due to LMA rotation (Fig. 5), and ventilation was inadequate in another 6 patients (10.4%). Three patients (5.2%) developed laryngospasm and inspiratory stridor after insertion, which caused inadequate ventilation. Also, none of these 3 patients needed reinsertion, as optimal placement was confirmed endoscopically (Fig. 6).

In the leakage test, 20 patients (34.5%) were found to be grade 1, 23 (39.7%) grade 2, 6 (10.3%) grade 3, and 5 (8.6%) grade 4. The ultrasound examination grade was 1 in 14 patients (24.1%), 2 in 33 patients (56.9%), 3 in 4 patients (6.9%), and 4 in 7 patients (12.1%). No patients were allocated scores of 5 or 6 (Table 3).

Spearman coefficient of rank correlation between these 2 grading systems was 0.616 ($P < .0001$). The weighted $\kappa$ value was 0.536, and standard error was 0.095. If the 3 cases of laryngospasm were excluded from the analysis, the coefficient of rank correlation was 0.713 ($P < .0001$). In this case, the weighted $\kappa$ value was 0.605, and standard error was 0.086. The strength of the correlation between the 2 systems is represented in scatter and diagraph plots (Fig. 7). The Bland-Altman scatter plot (Fig. 8) of the differences between these 2 grade systems showed insignificant bias or difference (mean, $-0.1724$) with limits of agreement ($-1.60$ to $+1.25$). And 82% of the plotted difference in grades were zero and scattered on x-axis.

Receiver operator characteristic curve analysis was based on fiberoptic evaluation of LMA position (Fig. 9), that suboptimal placement required reinsertion. If an ultrasound examination grade 4 (>3) was set as the threshold for reinsertion,

<table>
<thead>
<tr>
<th>Plane</th>
<th>Ultrasound examination presentation</th>
<th>Points</th>
</tr>
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<tbody>
<tr>
<td>THT</td>
<td>2 cuff shadows were not symmetrical (Fig. 4A, left)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cuff edge was not plumped but flat and rigid (Fig. 4A, right)</td>
<td>1</td>
</tr>
<tr>
<td>TLS</td>
<td>Cuff shadow did not displace the esophagus by shifting the transducer upward (Fig. 4B, left)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Edge of the cuff tip was distorted and the shape of the cuff was irregular (Fig. 4B, right)</td>
<td>1</td>
</tr>
<tr>
<td>PPL</td>
<td>Impossible to see the cuff tip and esophagus in the same plane by adjusting transducer</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cuff edge was distorted and obscure</td>
<td>1</td>
</tr>
</tbody>
</table>

THT = transverse plane between hyoid bone and thyroid bone; TLS = transverse plane of lateral suprasternal notch; PPL = parasagittal plane of pharynx and larynx.
the sensitivity and specificity both reached 100%, but with leakage grade 3 (≥2) as the threshold, the sensitivity and specificity were 85.7% and 94.1%, respectively (Table 4).

4. Discussion

We found that using ultrasound to confirm LMA placement was quick, noninvasive, and reliable. There is a great deal of

<table>
<thead>
<tr>
<th>Grades</th>
<th>Leakage</th>
<th>Ultrasound (points)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>No leak</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Moderate leak but satisfactory ventilation</td>
<td>1–2</td>
</tr>
<tr>
<td>3</td>
<td>Severe leak with inadequate ventilation</td>
<td>3–4</td>
</tr>
<tr>
<td>4</td>
<td>Total obstruction with impossible ventilation</td>
<td>5–6</td>
</tr>
</tbody>
</table>

Fig. 4  The ultrasound examination score system. A, Left: in THT plane, 2 cuff shadows are asymmetrical; right: 2 cuffs are not only asymmetrical but with plant and rigid edges. B, Left: in TLS plane, cuff tip does not displace the esophagus (circles indicate the place), whereas an irregular shadow (arrow) appears beside the trachea; right: edge of the cuff tip is distorted and the shape of the cuff was irregular. C, Left: in PPL plane, cuff shadow suddenly disappeared as there was a cutting edge. The cuff tip and esophagus cannot be found in the same plane; right: the cuff edge (*) is distorted and obscure. ESO = esophagus.
interest in using ultrasound in airway management. The main barrier to more widespread adoption is that ultrasound propagates poorly through the thyroid bone and air, and attenuates quickly. Moreover, ultrasound reflections at the air-mucosa border also create acoustic shadowing and some artifacts. Sometimes, a large epiglottis or a pre-epiglottic space filled with fat may also obstruct the view of laryngeal structures [5,6,9,15]. Fortunately, however, an appreciation of the detailed anatomy is not needed to confirm the position of the LMA. All requirements are views that can show surrounding structures, which can detect the tip of the cuff and confirming its correct orientation and contact with the larynx. In other words, the shape of the cuff and its relationship with surrounded structures are good enough to judge LMA’s placement from our findings. Any wrinkling or distortion of the cuff outline indicates twisting or folding.

Ultrasound examination is highly performance depended and subjective, not only in airway evaluation but also in other areas. It is the intrinsic nature of ultrasound technique, and sometimes the observer bias is inevitable. So we designed those “standard views” to keep the homogeneity between different practitioners. Also, we designed the score system similar as the clinical leakage system to reduce the observer bias.

The 3 standard image planes, 2 in the transverse and 1 in the sagittal plane, were designed based on spatial conformation of the pharynx and larynx to evaluate the location of the LMA. In the pharynx, even slight rotation of the LMA could be detected easily when 2 asymmetrical cuff shadows were visible in the THT plane. Severe rotation of the LMA would cause one of the cuff shadows to be much smaller and deeper than the other, and the edge of the cuff was flat and rigid rather than plump (Fig. 5A). Rotation, however, will not always impair ventilation. We found in one case that rotation caused folding of the epiglottis but did not completely obstruct the airway, with the leakage test showing a moderate leak but acceptable ventilation (Fig. 5B). Most of the time, the epiglottis could be seen in this plane. An epiglottic shadow visible above the cuff shadow indicated bending of the epiglottis just above the cuff or the air conduit, but this was not always a sign of epiglottic folding. In many cases, a fat epiglottis rested on the air conduit but did not fold, and the fiberoptic endoscope could be advanced below it.

**Fig. 5** Rotation of the LMA with acceptable ventilation. A, Two cuff’s shadows are asymmetrical and in different size. One of the edges is much smaller and deeper than the other one (arrow), and the cuff’s edge was flat and rigid rather than plump. B, Epiglottis was enfolding in the fiberoptic view of this case.

**Fig. 6** Fiberscope view of laryngospasm in 3 cases.
At the level of the larynx, in the TLS plane, we focused on the tip of the cuff and its spatial relationship with the proximal esophagus. The landmark of this plane is the esophagus itself, and the image quality is much better than the THT plane as it is not obscured by a large amount of air or the thyroid bone. Images in this plane must be acquired slightly lateral to the midline as the air-filled trachea lies directly anterior to the esophagus at this level. The TLS plane is the best at which to observe the shape of the cuff tip and its relationship to the proximal esophagus. Images were acquired in the PPL plane to show the LMA in its entirety. In this view, a smooth, sharp cuff profile in the shape of a snake’s head indicates optimal placement. It is important to note that even when a suction tube can be inserted through the drainage conduit, the tip of the cuff might not be sitting on the esophagus in its optimal position. We found that the suction tube could be advanced in 3 of the 6 cases in which reinsertion was required. In this plane, we sometimes found that the cuff tip and esophagus were separated and could not be seen in the same plane (Fig. 10), which differs from previous reports [4,16]. The inability to insert a suction tube should arouse clinical suspicion that the LMA is misplaced, but the ability to do so does not always indicate that the LMA is in a correctly location.

We also note that 3 of the cases (5.2% of the entire cohort) in which ventilation was inadequate but placement was confirmed as optimal by fiberscope were subsequently found to be caused by airway spasm due to inadequate depth of anesthesia (Fig. 6). When additional hypnotics or opioids were administered, the ability to ventilate returned, which explains why the receiver operator characteristic curve analysis found only 94.1% specificity for detecting misplacement when the leakage test result was used as the criterion. In contrast, the ultrasound examination grade in each of these 3 cases was less than 4, and the complication was identified using this technique. In these cases, the use of ultrasound would have avoided reinsertion and interruption of ventilation without the need for an unnecessary fiberoptic examination.

<table>
<thead>
<tr>
<th>Ultrasound examination grade</th>
<th>Leakage test grade</th>
<th>Total (frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total (frequency)</td>
<td>20 (34.5%)</td>
<td>29 (50.0%)</td>
</tr>
</tbody>
</table>

- a Inadequate ventilation due to airway spasm.
- b Need reinsertion confirmed by fiberscope.

**Table 3** Frequency table of leakage test grade and ultrasound examination grade

**Fig. 7** Scatter diagraph of 2 grading systems.
Our study has several limitations. We used only the LMA Supreme. The oropharyngeal leak pressure of the LMA Supreme is about 30 cm H2O, but is much lower in other kinds of supraglottic airway such as the iGel. Thus, the result of the leakage test may differ when other kinds of LMA are used. We enrolled a relatively small number of subjects, although there still had a significant result. Also, most subjects was female (50 cases), as most of the patients recruited underwent gynecologic surgery—the lack of male subjects may have influenced our findings. The size of the LMA inserted was determined mainly according to the manufacturer’s instructions and modified by the anesthesiologist according to clinical experience. A size 3 LMA was used in some women even when their weight exceeded 70 kg, and a size 4 LMA even when the body weight exceeded 90 kg based on the anesthesiologist’s experience. Another shortcoming is that we did not have equipment to monitor cuff pressure, which could have influenced the leakage test but not the ultrasound examination.

5. Conclusions

Ultrasound examination of the airway correlates strongly and has high agreement with the leakage test when determining the position of an LMA. Ultrasound is noninvasive, fast, and reliable and does not require ventilation to be interrupted. It has a broadly comparable ability to judge the positioning of an LMA as fiberoptic examination and to predict the need for reinsertion.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Criterion</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage test grade</td>
<td>≥ 1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&gt; 1</td>
<td>100</td>
<td>39.22</td>
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<tr>
<td></td>
<td>&gt; 2</td>
<td>85.71</td>
<td>94.12</td>
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<td></td>
<td>&gt; 3</td>
<td>57.14</td>
<td>98.04</td>
</tr>
<tr>
<td>Ultrasound examination grade</td>
<td>≥ 1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&gt; 3</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4  ROC analysis at different criteria for reinsertion

* Best threshold.
References


